Tanta University

Faculty of Engineering

ELECTRICAL POWER ENGINEERING (1)

DC DISTRIBUTION

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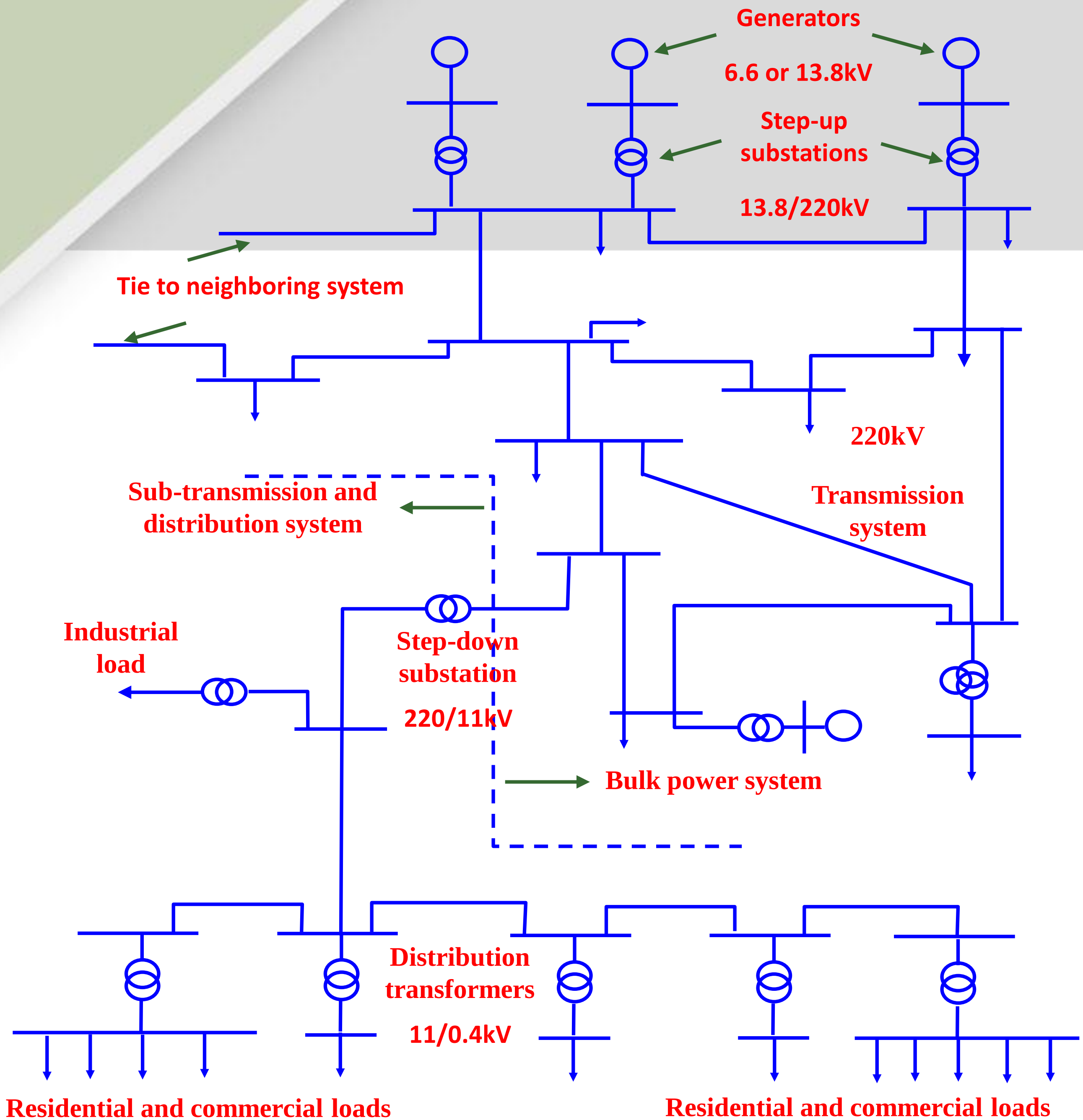
INTRODUCTION AND GENERAL BASICS OF POWER SYSTEMS



Generators
6.6 or 13.8kV
Step-up
substations
13.8/220kV
Tie to neighboring system
220kV
Transmission
system
Sub-transmission and
distribution system
Industrial
load
Step-down
substation
220/11kV
Bulk power system
Distribution
transformers
11/0.4kV
Residential and commercial loads
Residential and commercial loads

Transmission and Distribution of D.C. Power

By transmission and distribution of electric power is meant its conveyance from the central station, where it is generated, to places where it is demanded by the consumers like mills, factories, residential and commercial buildings, pumping stations etc.

Transmission and Distribution of D.C. Power

Methods of electric power transmission

- overhead system
- underground system

12.6 Overhead Versus Underground System

The distribution system can be overhead or underground. Overhead lines are generally mounted on wooden, concrete or steel poles which are arranged to carry distribution transformers in addition to the conductors. The underground system uses conduits, cables and manholes under the surface of streets and sidewalks. The choice between overhead and underground system depends upon a number of widely differing factors. Therefore, it is desirable to make a comparison between the two.

(i) *Public safety.* The underground system is more safe than overhead system because all distribution wiring is placed underground and there are little chances of any hazard.

(ii) *Initial cost.* The underground system is more expensive due to the high cost of trenching, conduits, cables, manholes and other special equipment. The initial cost of an underground system may be five to ten times than that of an overhead system.

(iii) *Flexibility.* The overhead system is much more flexible than the underground system. In the latter case, manholes, duct lines etc., are permanently placed once installed and the load expansion can only be met by laying new lines. However, on an overhead system, poles, wires, transformers etc., can be easily shifted to meet the changes in load conditions.

(iv) *Faults.* The chances of faults in underground system are very rare as the cables are laid underground and are generally provided with better insulation.

(v) *Appearance.* The general appearance of an underground system is better as all the distribution lines are invisible. This factor is exerting considerable public pressure on electric supply companies to switch over to underground system.

(*vi*) *Fault location and repairs.* In general, there are little chances of faults in an underground system. However, if a fault does occur, it is difficult to locate and repair on this system. On an overhead system, the conductors are visible and easily accessible so that fault locations and repairs can be easily made.

(*vii*) *Current carrying capacity and voltage drop.* An overhead distribution conductor has a considerably higher current carrying capacity than an underground cable conductor of the same material and cross-section. On the other hand, underground cable conductor has much lower inductive reactance than that of an overhead conductor because of closer spacing of conductors.

(*viii*) *Useful life.* The useful life of underground system is much longer than that of an overhead system. An overhead system may have a useful life of 25 years, whereas an underground system may have a useful life of more than 50 years.

(*ix*) *Maintenance cost.* The maintenance cost of underground system is very low as compared with that of overhead system because of less chances of faults and service interruptions from wind, ice, lightning as well as from traffic hazards.

(*x*) *Interference with communication circuits.* An overhead system causes electromagnetic interference with the telephone lines. The power line currents are superimposed on speech currents, resulting in the potential of the communication channel being raised to an undesirable level. However, there is no such interference with the underground system.

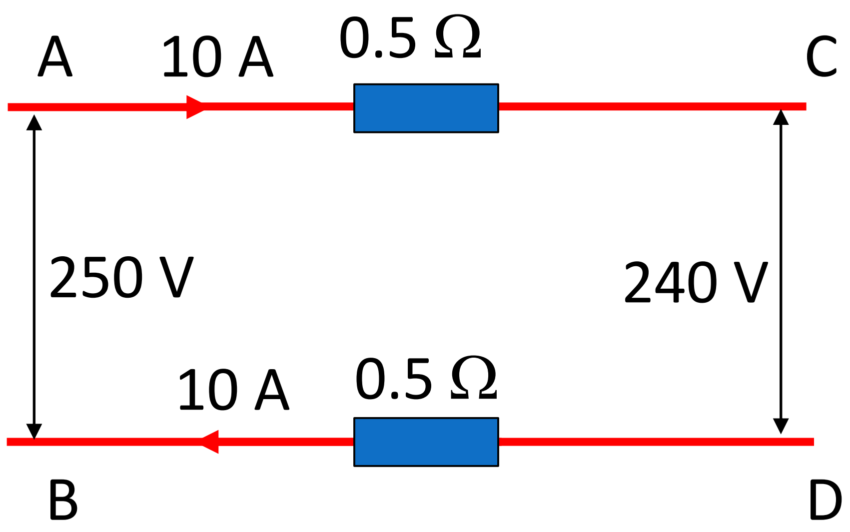
Transmission and Distribution of D.C. Power

A good system whether overhead or underground should fulfill the following requirements

- Voltage at consumer's terminals must be within ±5
- The loss of power in the system should be a small percentage (about 10%) of the power transmitted
- The transmission cost should not be excessive
- Maximum current through the conductor is limited to prevent conductor overheating and insulation injury

Voltage Drop and Transmission Efficiency

The difference in potential at the two ends is the potential drop in the cable



If the transmitting voltage is 250V, current in AC is 10A, and resistance of each feeder conductor is 0.5 Ω,

drop in each feeder conductor is 10*0.5 = 5 volt

drop in both feeder conductors is 5 * 2 = 10 V

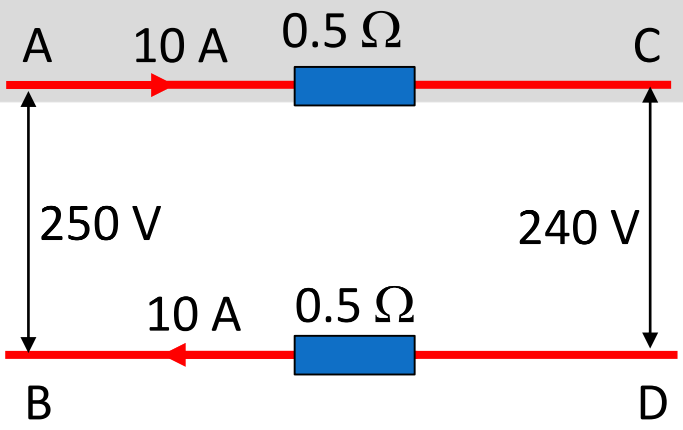
The potential difference at receiving end CD: 250 - 10 = 240 V

Voltage Drop and Transmission Efficiency

Input power at *AB* = 250*10= 2500W

Output power at *CD* =240*10=2400W

power lost in 2 feeders=2500-2400=100W



The power loss could also be found by using the formula:

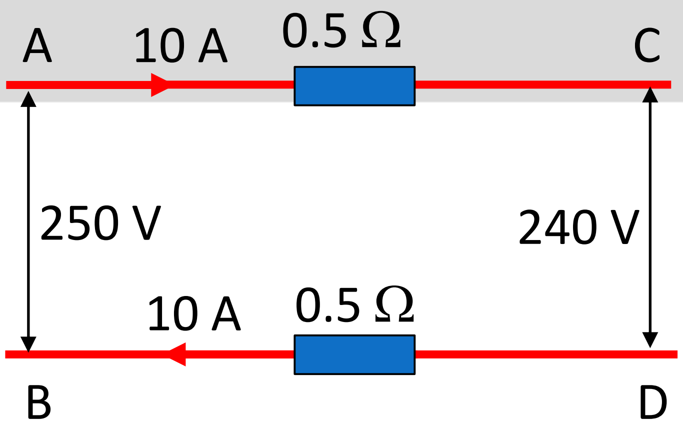
Power loss = $2\, I^2 * R = 2 * 10^2 * 0.5 = 100W$

The transmission efficiency is the ratio of output to input:

$$\text{Efficiency of the transmission} = \frac{\textit{Power delivered to the line}}{\textit{Power received by the line}}$$

Voltage Drop and Transmission Efficiency

$$\eta = \frac{Power\ \ delivered\ \ to\ \ the\ \ line}{Power\ \ received\ \ by\ \ the\ \ line}$$



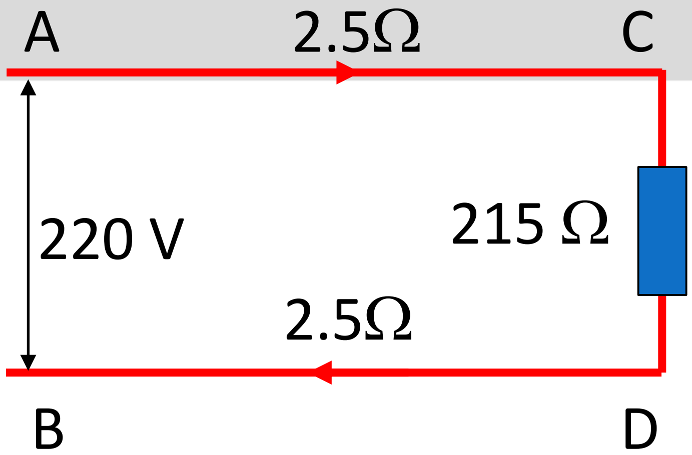
Power delivered by the *feeder* is 2400W and power received is 2500W

η = 2400*100/2500 = 96%

<u>Example:</u> A DC 2-wire feeder supplies a constant load with a sending-end voltage of 220 V. If the load resistance is 215 Ω and the total feeder resistance is 5Ω, calculate the load voltage, voltage drop, and feeder efficiency.

Voltage Drop and Transmission Efficiency

Example: A DC 2-wire feeder supplies a constant load with a sending-end voltage of 220 V. If the load resistance is 215 Ω and the total feeder resistance is 5Ω, calculate the load voltage, voltage drop, and feeder efficiency.



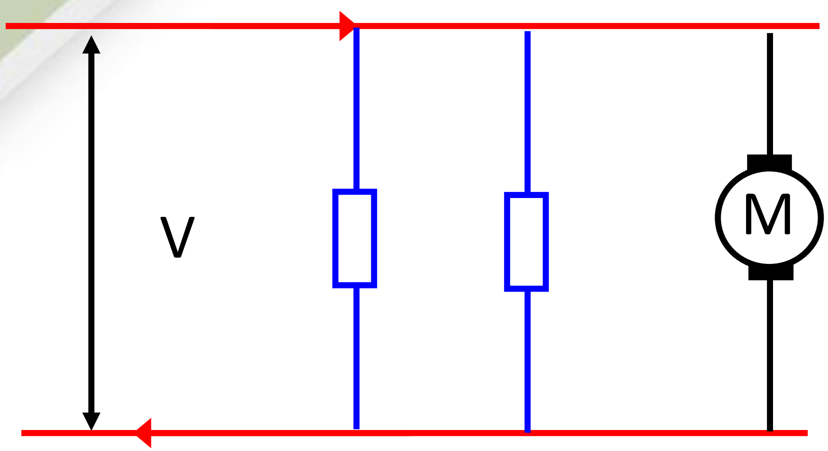
Solution: $I = V_1 / (R_t + R_L) = 220/(5+215) = 1A$

Voltage drop $= I * R_t = 1*5 = 5$ V

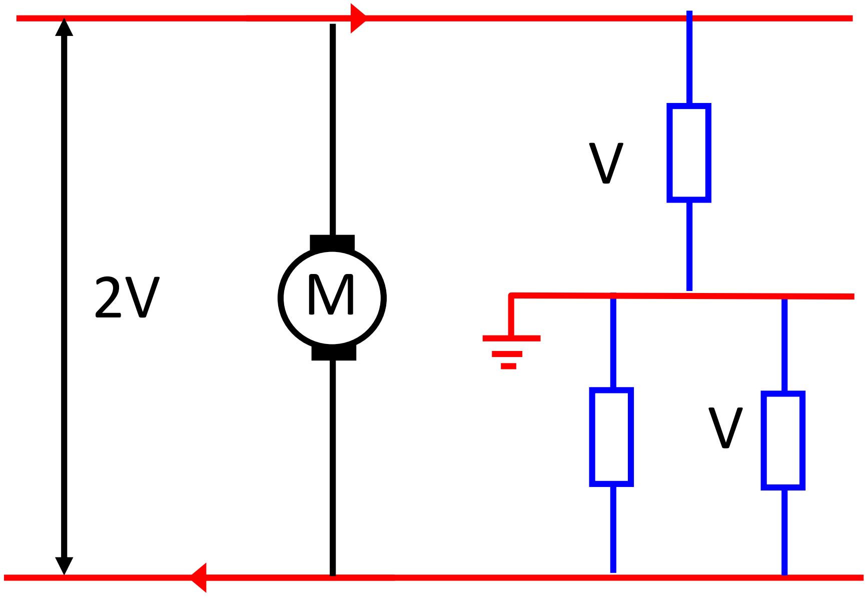
$V_2 = V_1 -$ Voltage drop $= 220-5 = 215$ V.

$\%\eta = (V_2 I / V_1 I)*100 = (V_1 / V_2)*100 = 215/220*100 = 97.73\%$

Types of DC distribution



a) 2-wire system

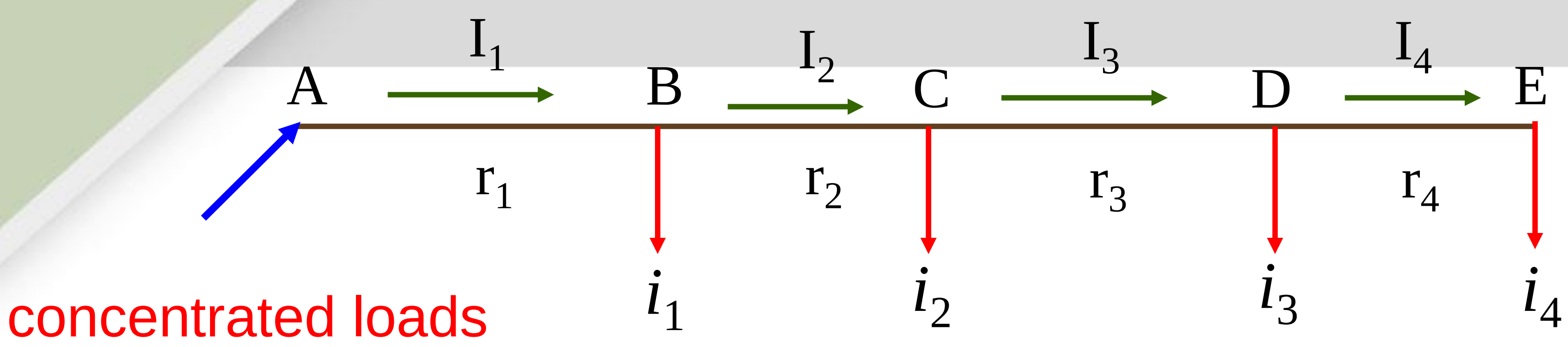


b) 3-wire system

Methods of Feeding a Distributor

- Feeding at one end
- Feeding at both ends with equal voltages
- Feeding at both ends with unequal voltages
- Ring distributor

D.C. distributor fed at one end



$$\mathbf{I_1 = \boldsymbol{i}_1 + \boldsymbol{i}_2 + \boldsymbol{i}_3 + \boldsymbol{i}_4} \qquad \mathbf{I_2 = \boldsymbol{i}_2 + \boldsymbol{i}_3 + \boldsymbol{i}_4}$$

$$\mathbf{I_3 = \boldsymbol{i}_3 + \boldsymbol{i}_4} \qquad \mathbf{I_4 = \boldsymbol{i}_4}$$

$$\Delta V = I_1 * r_1 + I_2 * r_2 + I_3 * r_3 + I_4 * r_4$$

$$\Delta V = r_1 (i_1 + i_2 + i_3 + i_4) + r_2 (i_2 + i_3 + i_4) + r_3 (i_3 + i_4) + r_4 i_4$$

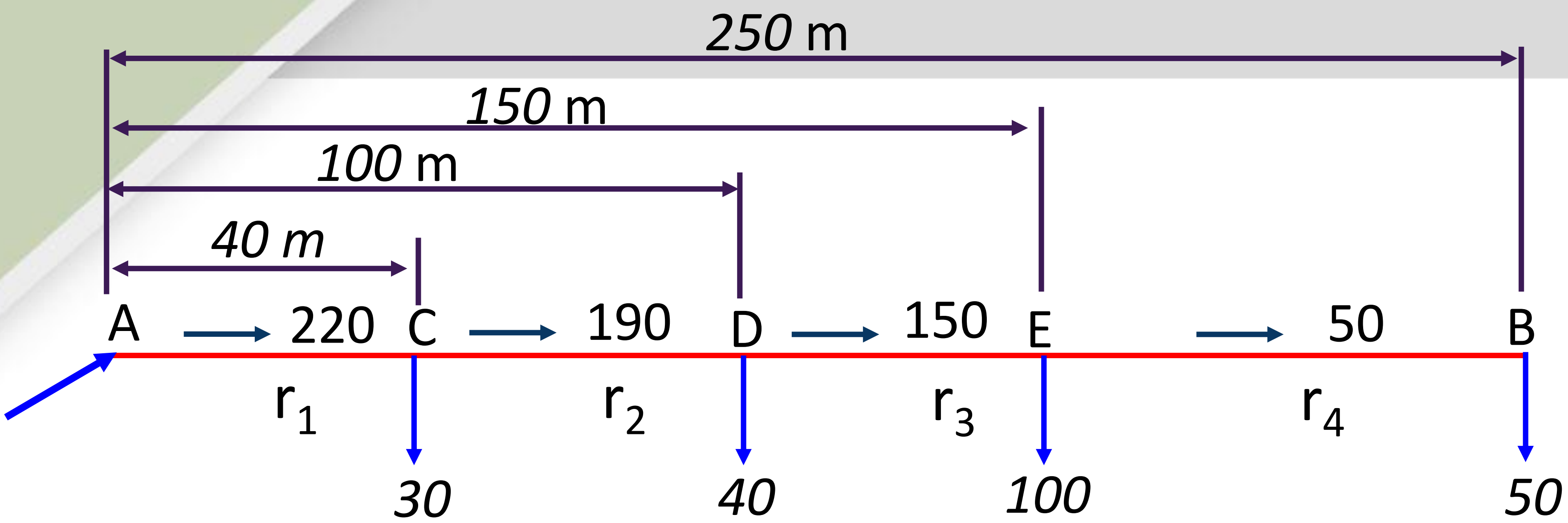
D.C. distributor fed at one end

Example: A 2-wire d.c, distributor AB is 250 meters long. It is fed at point A. The various loads and their positions are given below:

Point	distance from A (m)	concentrated load (A)
C	**40**	**30**
D	**100**	**40**
E	**150**	**100**
B	**250**	**50**

If the maximum permissible voltage drop is not to exceed 10 V, find the cross sectional area of the distributor. Take $\rho = 1.78 * 10^{-8}\ \Omega$-m.

D.C. distributor fed at one end



$\Delta V = 2 * \rho / a * (40*220+60*190+50*150+100*50) = 10V$

$10 = 2*1.78*10^{-8} / a * (32700)$

$a = 0.000116412\ m^2$

$a = 1.16412\ cm^2$

Distributor fed at both ends

It is desirable for long distributors to be fed at both ends instead of at one end

Feeding at both ends reduces the <u>voltage drop</u> without increasing the cross-section of the conductor

The two ends of the distributor may be supplied with:

(i) Equal voltages **(ii) Unequal voltages**

Distributor fed at both ends

Advantages

(*a*) If a fault occurs on any feeding point of the distributor, the continuity of supply is maintained from the other feeding point.

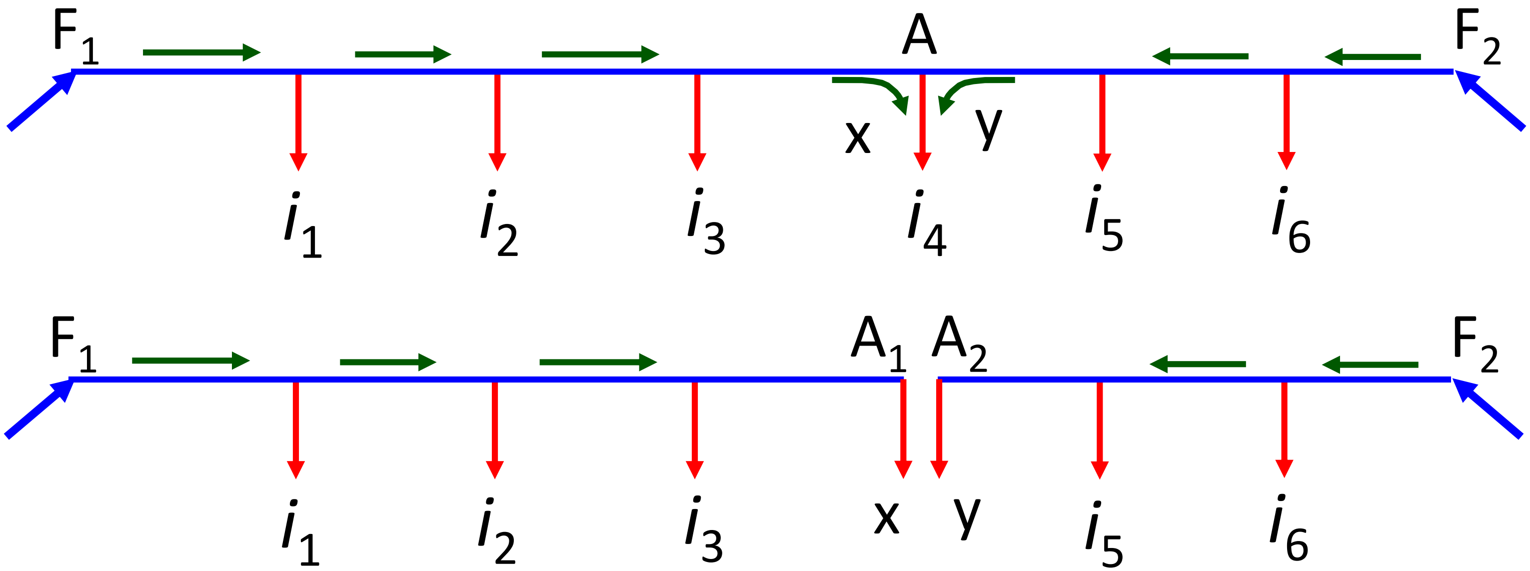
(*b*) In case of fault on any section of the distributor, the continuity of supply is maintained from the other feeding point.

(*c*) The area of X-section required for a doubly fed distributor is much less than that of a singly fed distributor.

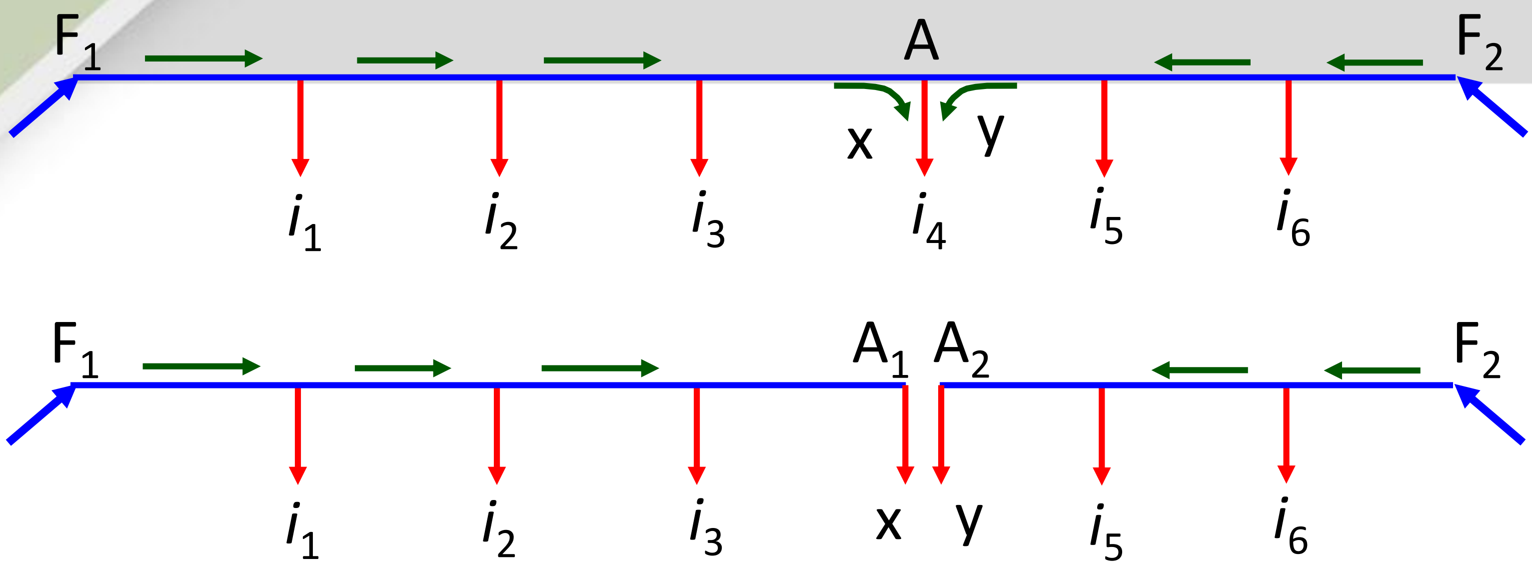
Distributor fed at both ends with equal voltages

(i) the maximum voltage drop must always occur at one of the load points

(ii) since both feeding ends are at the same potential, then the voltage drop between each end and this point must be the same



Distributor fed at both ends with equal voltages



$x + y = i_4$

drop from F_1 to A_1 = drop from F_2 to A_2

Total voltage drop from F_1 to F_2 = 0.0

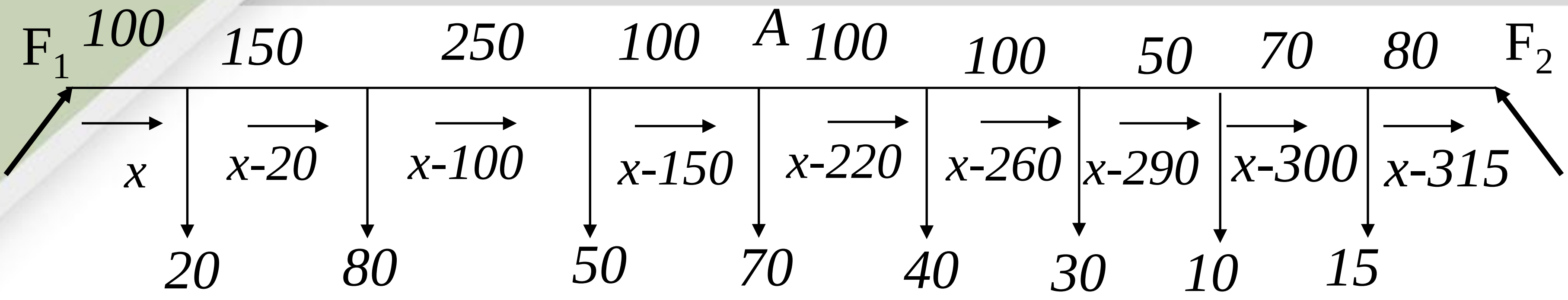
Distributor fed at both ends with equal voltages

Example: A 2-wire dc distributor F_1 F_2 1000 meters long is loaded as:

Dist. from F_1 (m):	100	250	500	600	700	800	850	920
Load (A):	20	80	50	70	40	30	10	15

The feeding points F_1 and F_2 are maintained at the same potential. Find which point will have the minimum potential and what will be the drop at this point? Take the cross section of the conductors as 0.35 cm^2 and specific resistance of copper as $1.764*10^{-6}$ Ω-cm.

Distributor fed at both ends with equal voltages



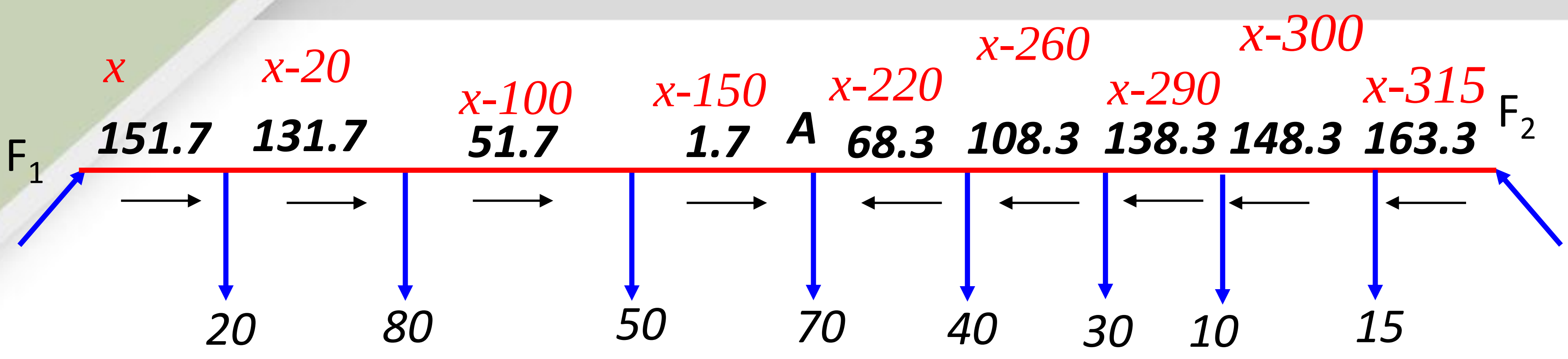
Total voltage drop from F_1 to F_2 = 0

$0 = \rho/a*(100\,x + 150*(x-20) + 250*(x-100) + 100*(x-150) + 100*(x-220) + 100*(x-260) + 50*(x-290) + 70*(x-300) + 80*(x-315))$

$1000\,x = 151700 \rightarrow x = 151.7$ A

Distributor fed at both ends with equal voltages

x=151.7 A



Maximum voltage drop "At point A" is:

$$\Delta V_A = \rho/a*(100\ x + 150*(x\text{-}20) + 250*(x\text{-}100)$$

$$= 2*\ 1.764*10^{-8} / 0.000035 * (100*151.7 + 150*131.7$$

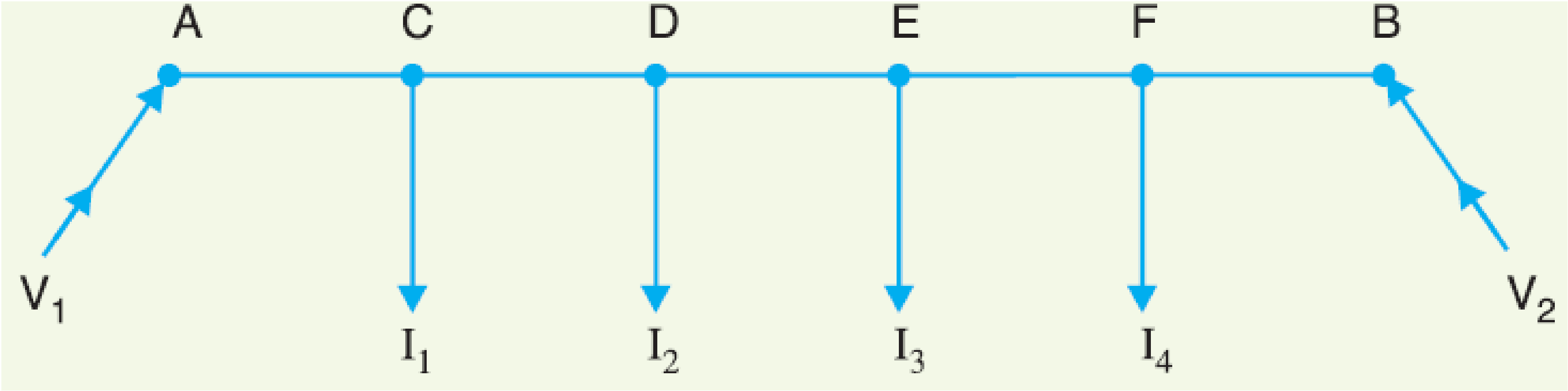
$$+ 250*51.7) = 48.3\ V$$

Distributor fed at both ends with unequal voltages

The point of minimum potential can be found by following the same procedure as discussed above

Voltage drop between A and B =Voltage drop over AB

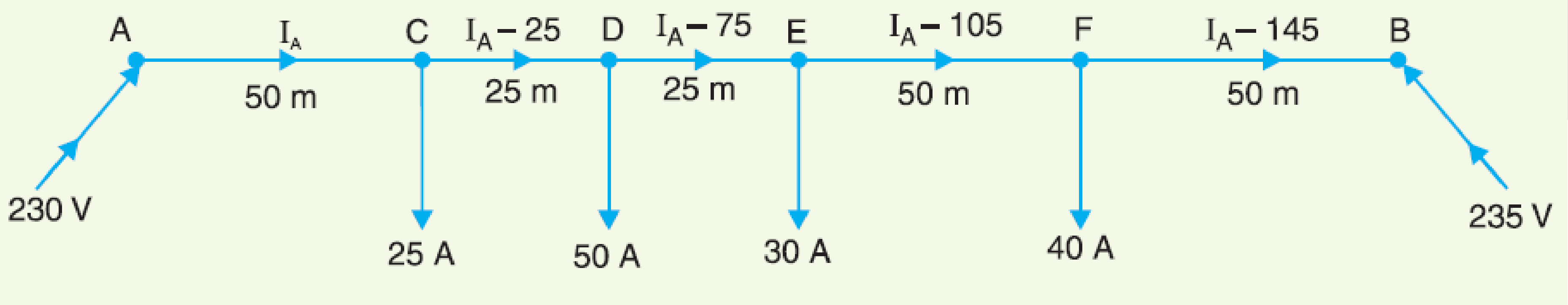
$V_1 - V_2$ = Voltage drop over AB



Distributor fed at both ends with unequal voltages

Example: A 2-wire d.c. distributor AB is fed from both ends. At feeding point A, the voltage is maintained at 230 V and at B 235 V. The total length of the distributor is 200 m and loads are tapped off as under:
25 A at 50 m from A; 50 A at 75 m from A, 30 A at 100m from A and 40 A at 150 m from A
The resistance per km of one conductor is 0.3 Ω. Calculate: (i) currents in various sections of the distributor (ii) minimum voltage and the point at which it occurs

Distributor fed at both ends with unequal voltages



Solution: Resistance of 1000 m length of distributor (both wires) $=2\times0.3= 0.6\ \Omega$

Resistance of section AC, $R_{AC}=0.6\times50/1000=0.03\Omega$

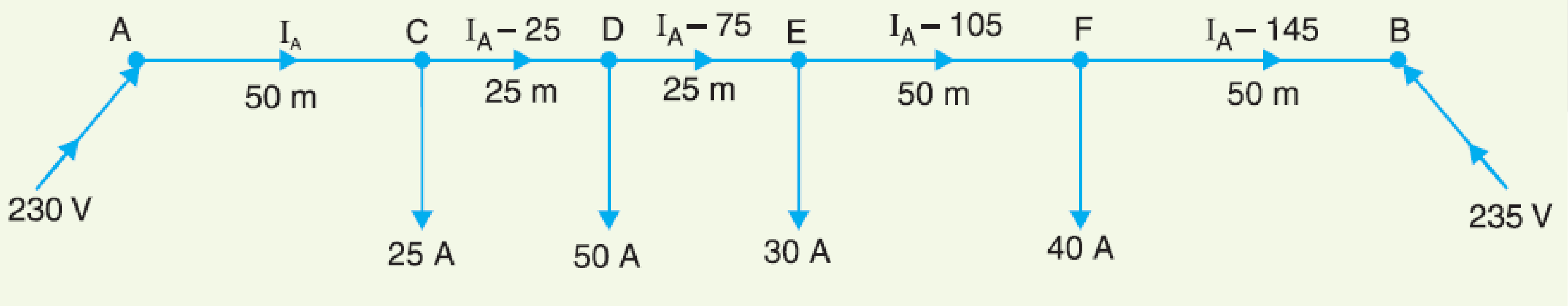
Resistance of section CD, $R_{CD}=0.6\times 25/1000 = 0.015\ \Omega$

Resistance of section DE, $R_{DE}=0.6\times 25/1000 = 0.015\ \Omega$

Resistance of section EF, $R_{EF}=0.6\times 50/1000 = 0.03\ \Omega$

Resistance of section FB, $R_{FB}=0.6\times 50/1000 = 0.03\ \Omega$

Distributor fed at both ends with unequal voltages



Voltage at B=Voltage at A - drop over AB

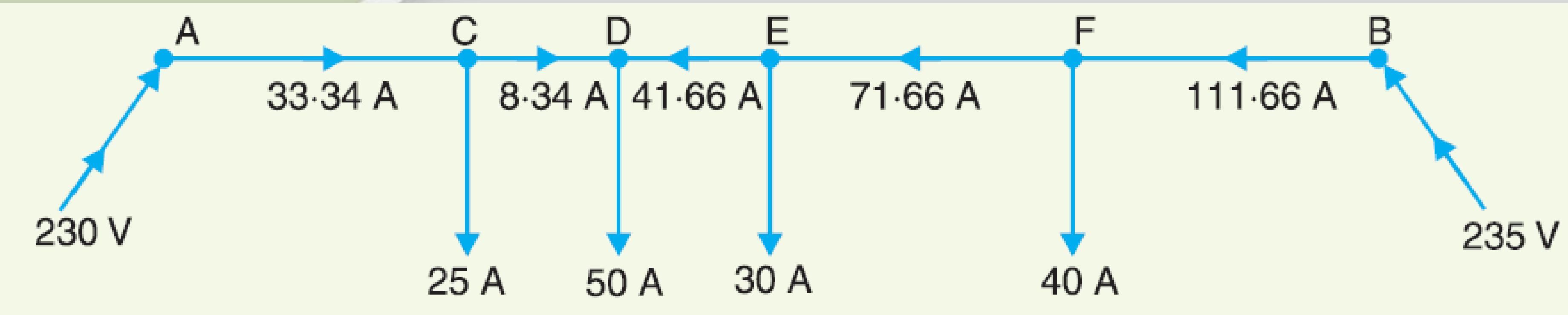
$V_B = V_A - [I_A R_{AC} + (I_A - 25) R_{CD} + (I_A - 75) R_{DE} + (I_A - 105) R_{EF} + (I_A - 145) R_{FB}]$

$235 = 230 - [0.03\ I_A + 0.015\ (I_A - 25) + 0.015\ (I_A - 75) + 0.03\ (I_A - 105) + 0.03\ (I_A - 145)]$

$235 = 230 - [0.12\ I_A - 9]$

$$I_A = \frac{239 - 235}{0 \cdot 12} = 33 \cdot 34\ \text{A}$$

Distributor fed at both ends with unequal voltages



Current in section AC, $I_{AC} = I_A = 33{\cdot}34$ A

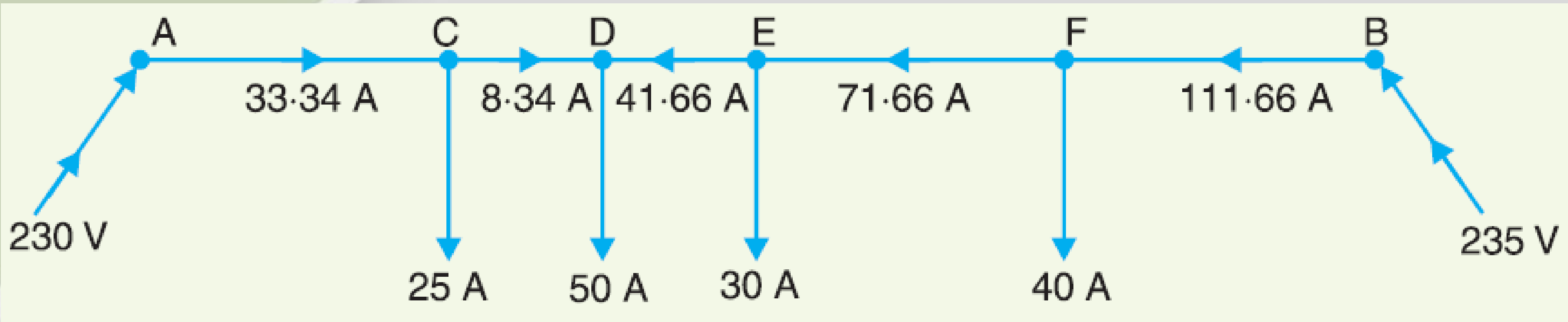
Current in section CD, $I_{CD} = I_A - 25 = 33{\cdot}34 - 25 = 8{\cdot}34$ A

Current in section DE, I_{DE}=IA-75 = 33·34-75 = - 41·66 A from D to E Or 41·66 A from E to D

Current in section EF, I_{EF}=IA-105 = 33·34-105 = −71·66 A from E to F OR 71·66 A from F to E

Current in section FB, I_{FB}=IA-145 = 33·34-145 = -111·66 A from F to B OR 111·66 A from B to F

Distributor fed at both ends with unequal voltages



Load point D is the point of minimum potential.

Voltage at D, $V_D = V_A - [I_{AC} R_{AC} + I_{CD} R_{CD}]$

$= 230 - [33.34 \times 0.03 + 8.34 \times 0.015]$

$= 230 - 1.125 = 228.875$ V